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Shunt Capacitor Position and Size Selection for Radial Distribution System using GA

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ABSTRACT

This paper presents a new approach for shunt Capacitor position and size for radial distribution network based on genetic approach. Distribution networks experience distinct changes from low load level to high load level every day. In certain industrial areas, it has been observed that under certain critical loading conditions, the distribution system experience voltage collapse. Due to this phenomenon, system voltage collapses periodically and urgent reactive compensation needs to be supplied to avoid repeated voltage collapse. In this Paper a new approach for finding Capacitor size and Position presented .The node having the voltage stability index minimum is more prone to voltage collapse. That node is identified as candidate node. Further capacitors are installed at the candidate nodes for improvement of Voltage stability index. Genetic Algorithm is more suitable for such problems. So Genetic Algorithm is used for sizing of capacitors at selected locations.

Keywords: *Stability index, Vector based distribution load flow, size Capacitor, capacitor location, Radial Distribution system and genetic algorithm*

I. INTRODUCTION

In order to provide (i) better quality of power supply to consumers (ii) to minimize the energy losses and (iii) for design and up gradation of distribution system, Position and size of capacitor plays an important role in compensating equipment design. The I^2R loss in a distribution system is significantly high compared to that in a high-voltage transmission system. The pressure of improving the overall efficiency of power delivery has forced the power utilities to reduce the loss especially at the distribution level. The I^2R loss in a distribution system can be reduced by network reconfiguration. The reconfiguration changes the path of power flow from source to the loads. The loss can also reduced by adding shunt capacitors to supply part of the reactive power demand. Shunt capacitors can be installed in a distribution system to reduce energy and peak demand losses, release the kVA capacities of distribution apparatus, and also improve the system voltage profile and simultaneously with the installation of shunt capacitors the voltage stability limit also increases. This is indicated by the voltage stability index at each node calculated along with the load flow solution**.**

In this paper, Genetic approach design is proposed for selecting the capacitor size and location for radial distribution networks. Genetic algorithm has the ability to provide the optimal or near optimal solution even when the search space is large.

II. PROBLEM FORMULATION

Vector Based Distribution load flow method (VDLF) is used for load flow analysis. The following assumptions are considered in the distribution load flow:

1. Three phase radial distribution networks are balanced and can be represented by their equivalent single line diagram
2. Half-line charging susceptances of distribution lines are negligible and these distribution lines are represented as short lines.

Consider a line connected between two nodes as shown in Fig 2.1

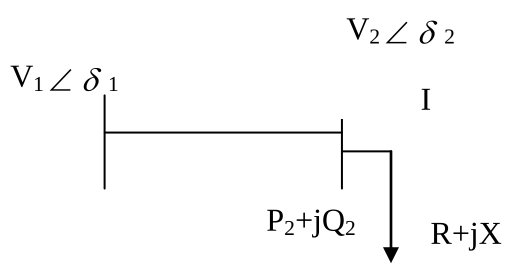

Fig: 2.1: Electrical Equivalent of Line Connected Between two Nodes of a Distribution Line.

The phasor diagram of this line

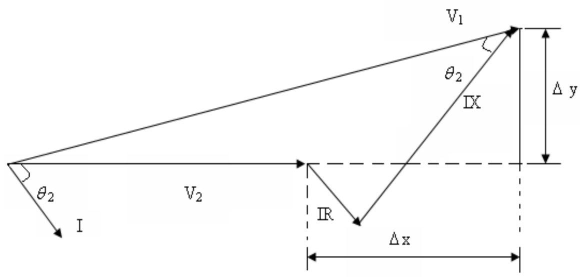

Fig: 2.2 Basic Phasor Diagram of a Line Connected Between two Nodes.

From fig 2.2 the following equations are derived

$V_1^2= (V_2+\Delta x)^2+ \Delta y^2$ --------2.1

where $\Delta x=IR \cos(\theta_2) + IX \sin(\theta_2)$ _2.2 3.2

$\Delta y=IX \cos(\theta_2) - IR \sin(\theta_2)$—2.3

Using the equations 2.2 and 2.3 in 2.1 we have

$V_1^2= (V_2+ IR \cos(\theta_2) + IX \sin(\theta_2))^2+ (IX \cos(\theta_2) - IR \sin(\theta_2))^2$

$V_1= [(V_2+ IR \cos(\theta_2) + IX \sin(\theta_2))^2+ (IX \cos(\theta_2)- IR \sin(\theta_2)^2]^{1/2}$ -----2.4

To eliminate I from the equation 2.4 use

$I \cos(\theta_2) = P_2/ V_2$

$I \sin(\theta_2) = Q_2/ V_2$

Where

P_2=Total active power load including active power loss beyond node 2.

Q_2= Total reactive power load including reactive power loss beyond node 2.

Thus $\Delta x= IR \cos(\theta_2) + IX \sin(\theta_2)$

$= (P_2R+Q_2X)/V_2$

$\Delta y= IX \cos(\theta_2) - IR \sin(\theta_2)$

$= (P_2X-Q_2R)/V_2$

Thus equation 2.4 becomes

$V_1^2= (V_2+ (P_2R+Q_2X)/V_2)^2+ ((P_2X-Q_2R)/V_2)^2$

$=V_2^2+2V_2(P_2R+Q_2X)/V_2+ P_2R+Q_2X)^2/V_2^2+ (P_2X-Q_2R)^2/V_2^2 V_1^2 V_2^2=V_2^4+(P_2R+Q_2X)^2+2V_2^2(P_2R+Q_2X)+$
$(P_2X-Q_2R)^2V_2^4+2 V_2^2 (P_2R+Q_2X) + (P_2^2+Q_2^2)$
$(R_2^2+X_2^2) - V_1^2 V_2^2=0$

$V_2^4+2 V_2^2 (P_2R+Q_2X-V_1^2/2) + (P_2^2+Q_2^2)$
$(R_2^2+X_2^2) =0$ -------2.5

$V_2=\{[(P_2R+Q_2X-0.5V_1^2)-(P_2^2+Q_2^2)(R_2^2+X_2^2)]^{1/2} + (P_2R+Q_2X-0.5V_1^2)\}^{1/2}$ ---2.6

The equation 2.6 can be written in general form as

$V_2= (B[j]-A[j])^{1/2}$ -----2.7

where subscript '2' is the receiving end of j^{th} branch. subscript '1' is the sending end of j^{th} branch

$A[j] = P_2R[j] +Q_2X[j]-0.5V_1^2$ ---2.8

$B[j] = [A[j]^2- (P_2^2+Q_2^2) (R[j]^2+X[j]^2)]^{1/2}$ --2.9

Let Ploss[j] and Qloss[j] be the real and reactive power loss of branch 'j

$Ploss[j] =R[j]* (P_2^2+Q_2^2)/V_2^2$ -- 2.10

$Qloss[j] =X[j]* (P_2^2+Q_2^2)/V_2^2$ -- 2.11

Phase Angle Calculation

$I_1=(V_1\angle\delta_1-V_2\angle\delta_2)/|Z|\angle\theta$--- 2.12

$P_{2effect}+ Q_{2effect}= V_2\angle\delta_2*I^*$ --- 2.13

from equations 3.12 and 3.13 we can write

$P_{2effect}+ Q_{2effect}= V_2\angle\delta_2 (V_1 \angle-\delta_1- V_2 \angle-\delta_2)/ |Z|\angle-\theta$
$= (V_2\angle\delta_2 *V_1\angle-\delta1-V2\angle -\delta_2* V_2\angle -\delta_2)/ |Z|\angle-\theta$
$=V_2* V_1\angle(\delta_2- \delta_1) - V_2* V_2\angle(\delta_2- \delta_2) /|Z|\angle-\theta$

$P_{2effect}=V_1* V_2 \cos(\delta_{21}+\theta)/|Z|-V_2\cos(\theta)/|Z|$

$\cos(\delta_{21}+\theta) = (|Z|/ (V_1V_2))*[P_{2effect}+ (V2 *V_2) \cos(\theta)/|Z|] = (|Z|/ (V_1V_2))*[P_{2effect}+ (V2 {/}V_1)*\cos(\theta)]$

Let $x= \delta_{21}+\theta y= (|Z|/ (V_1V_2))*[P_{2effect}+ (V2 {/}V_1)*\cos(\theta)]$

Then $x=\cos^{-1}(y)$
$x= \delta_2 -\delta_1+\theta$
herefore $\delta2=x+\delta_1-\theta$ -----2.12

III. GENETIC ALGORITHM

1. Read the system data.
2. Form idegree, itag, adjq & adjl vectors*.
3. Calculate effective load at each bus starting from the last bus.
4. Initialize the population.
5. Set the iteration count to '1'.
6. Set chromosome count equal to '1'. (i.e. w=1)
7. Decode the chromosomes of the population and determine the conductor number from the normalized form.
8. Run the load flow.
9. Calculate the objective function, given by Equation.

10. Calculate the fitness value of the Chromosome, using the formula

    Fit[w]=1.0/(1+0.005*obj[w]);
    Where w=chromosome count.

11. Repeat the procedure from step 7 for all chromosomes.
12. Sort the chromosomes and all their related data in the descending order of fitness.
13. Calculate the error (Fit[1]-Fit[ps]).
14. Check if the error is less than 0.0001&check whether voltage and current constraints are satisfied, if yes go to 19.
15. Now copy first 20% (i.e. % of elitism) of old population chromosomes into the next population.
16. By applying Roulette-Wheel technique generate two off springs. Then apply crossover and mutation operators respectively on them.
17. Now replace old population with new population.
18. Increment iteration count. If iteration count Greater than the max. Count, go to 6. Else goto 20.

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* Idegree vector indicates the number of lines connected to each bus. itag vector indicates the reservation allocated for each bus.

adjq vector shows the adjacent bus number and adjl vector shows the adjacent line number.

19. Print the message "problem is converged". Print the Capacitor size, location and converged voltages.
20. Print the message "maximum number of iterations have reached, yet the problem has not converged".

IV. TEST CASE

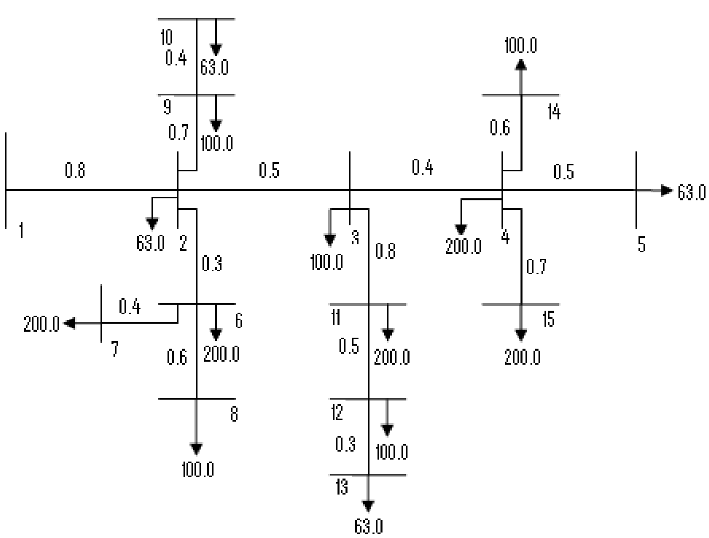

Fig 4.1: Single Line Diagram of 15 Bus System

Table (1): Converged Voltages, Phase Angles and Stability Index Values for 15-Bus system

Bus No.	Converged Voltages (in.p.u)	Phase Angles (Degrees)	Stability Index
1	1	0	1
2	0.97128	0.00065	0.88843
3	0.95667	0.00101	0.83723
4	0.9509	0.00115	0.81755
5	0.94992	0.0014	0.81422
6	0.95823	0.00386	0.84278
7	0.95601	0.00442	0.8353
8	0.95695	0.00418	0.83862
9	0.96797	0.00147	0.87789
10	0.9669	0.00173	0.87402
11	0.94995	0.00268	0.81426
12	0.94583	0.00372	0.80026
13	0.94452	0.00405	**0.79586**
14	0.94861	0.00173	0.80973
15	0.94844	0.00177	0.80916

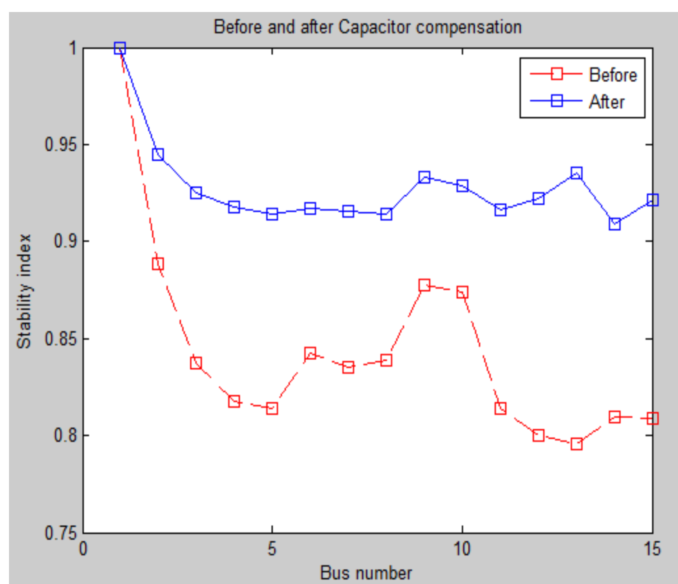

Fig 4.2: Stability Index for 15 Bus System Before and after Compensation

Table (2): Capacitor Location and Size (in p. u.) Using G A

Capacitor Location (Bus No.)	Capacitor Size (in p.u.)	Minimum stability index achieved at bus no.	Total Real Power Losses (in p.u.)
13	4.125	15	0.4938
13 15	4.125 5.1875	7	0.40834
13 15 7	4.125 5.1875 2.9375	8	0.36413
13 15 7 8	4.125 5.1875 2.9375 0.6875	14	0.36189

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